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Combustion turbine rotor blade coolant passage structure - has tapered section to avoid root region over-cooling

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A combustion turbine rotor blade (10) with a root section (12) from which extends an aerofoil section (14) has internal holes from root to tip. The pref. circular holes taper from root to mid-section (18) so that the reduced flow and heat transfer coefficient in the root region eliminate root region overcooling.

Hole taper may be linear or non-linear. The holes may increase in area towards the tip to avoid tip region overcooling. The optimised flow allows reduced coolant supply pressure and flow rate.

ADVANTAGE - Improved cooling performance and ease of mfr. (10pp Dwg.No.1/4)

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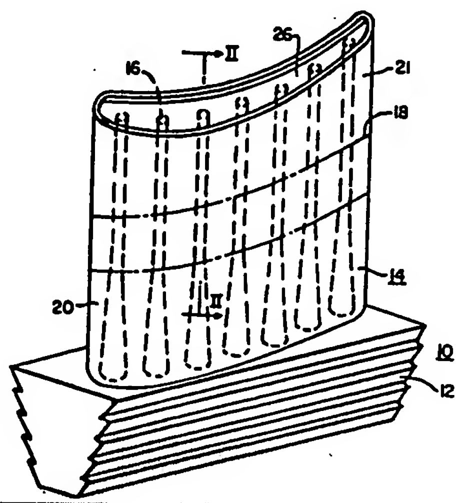

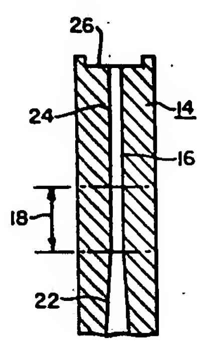

FIG.2.

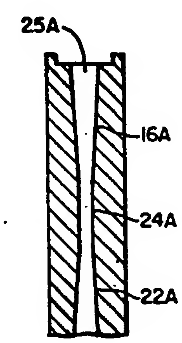

FIG.3.

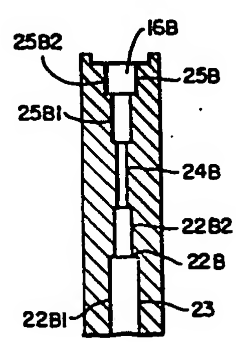

FIG.4.

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(54) **Improved coolant passage structure for rotor blades in a combustion turbine.**

(57) A combustion turbine rotor blade is provided with an airfoil portion having a plurality of coolant holes extending radially outwardly therethrough. The coolant holes are tapered to a smaller flow cross-section in the radially outward direction to produce more uniform cooling action over the length of the holes over which tapering is provided.

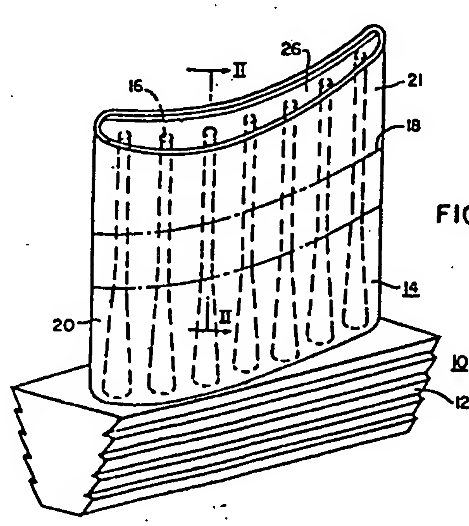

FIG.1.

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IMPROVED COOLANT PASSAGE STRUCTURE FOR ROTOR BLADES IN A COMBUSTION TURBINE

The present invention relates to rotor blades in a combustion turbine and more particularly to coolant systems therefor.

Rotating turbine blades are frequently cooled with air flowing radially outward through a plurality of holes which pass from the blade root to the blade tip. In prior art, the holes typically have either a constant diameter along the airfoil and root portions of the holes or a first constant diameter along the airfoil portion and a second constant diameter along the root portion of the holes. The diameter of the hole along the root portion typically being larger to avoid pressure loss in a region that does not require appreciable cooling. The airfoil portions of the coolant holes need to be relatively small in cross section to produce the high coolant velocity and heat transfer coefficient required there.

The critical design region of the blade for both stress and cooling is the center span portion of the blade, and the hole diameter, the number of holes and the coolant flow are normally set by design considerations. Since the coolant heats up appreciably as it flows outwardly along the blade, having received heat from the hot blade path gas, the coolant temperature at the center span region becomes considerably higher than the coolant temperature near the blade hub.

The lower coolant temperature near the blade hub tends to cool the blade to a lower temperature than is needed from the standpoint of stress design. Overcooling near the blade hub means the coolant absorbs more heat than necessary from the hub region which results in increased coolant temperature in the center span region and thus higher coolant flows and/or higher metal temperatures than if the overcooling did not occur.

Since reduced centrifugal stress usually more than offsets the coolant heatup in the blade tip region, overcooling also tends to occur there. An important consequence of overcooling in both the hub and tip regions is a higher level of pressure loss than would be encountered if the coolant flow per unit of flow area in overcooled regions were reduced to produce a heat transfer level matching the cooling requirements. Reduction of pressure loss in overcooled regions would make possible higher cooling flow per unit of flow area in the mid-span region in order to provide increased cooling for a given supply pressure at the blade root. This can be translated into a design for higher turbine inlet temperature or one with reduced cooling flow for given turbine inlet temperatures.

Further, in the process of manufacturing rotor blades by casting, cores are typically used to form the radial coolant holes in a blade. Structural weakness of the cores has resulted in core breakage and blade scrapping more frequently than desirable thereby adding to per unit manufacturing costs of blades.

Accordingly, it is a primary object of the invention to provide a new blade structure having improved coolant passage resulting in more efficient cooling, better turbine operation and greater manufacturing efficiency.

With this object in view, the present invention resides in a combustion turbine rotor blade having a root portion and an airfoil portion extending therefrom, said airfoil portion having a plurality of coolant holes extend-

ing from said root portion along its span to its tip to provide flow of coolant therethrough from said root portion, each of said coolant holes having an inner hub portion and a second portion extending outwardly from said hub portion, characterized by said hub and second hole portions having relative flow areas which cause the coolant to have reduced flow per unit of flow area in said hub hole portion relative to the coolant flow per unit of flow area through said second hole portion over a mid-span region of said blade thereby avoiding hub blade region overcooling.

The preferred embodiment of invention will be described, by way of example, with reference to the accompanying drawings in which:

Figure 1 shows a perspective view of a combustion turbine blade having coolant passages in accordance with the principles of the invention;

Figure 2 shows a portion of the blade airfoil illustrating the tapered hole structure preferred for the blade coolant holes in the blade of Figure 1; and

Figures 3 and 4 illustrate alternative embodiments with variations in the tapered coolant hole structure in accordance with the invention.

There is shown in Figure 1 a combustion turbine blade 10 having a root portion 12 and an airfoil portion 14 arranged in accordance with the principles of the invention. Coolant holes or channels 16 extend radially outwardly along the span of the blade. Air flow supplied from complementary coolant holes in the blade root and directed outwardly along the coolant holes 16 cools the blade airfoil portion 14 and its surface which is exposed to the hot blade path gas.

A center span portion 18 of the blade airfoil is the critical design region for which the number of holes, the hole diameter and the coolant flow are set to meet its cooling needs. The total blade coolant system structure is then designed to support the critical region needs.

The temperature of the coolant in the holes 16 is lower in a blade hub region 20 than in the mid-span region 18 because the coolant heats up as it flows outwardly along the blade. In prior art designs, the lower temperature coolant tends to overcool the blade hub 20 resulting in coolant temperature in the mid-span region 18 being higher than it would be if overcooling did not occur. In turn, coolant flow and/or metal temperature is higher than it could be if coolant temperature rise were reduced with the elimination of overcooling.

With coolant hole structure provided in accordance with the invention, blade hub overcooling is substantially reduced or eliminated to permit lower coolant flow and/or lower metal temperature resulting in greater cooling and turbine efficiency.

Referring to Figure 2, the coolant hole 16 includes a hub portion 22 and an outer portion 24 which extends from the hub portion 22 through the blade mid-span region to the blade tip 26.

The hub portion 22 of the coolant hole 16 is tapered from a first diameter at its inlet end to a smaller diameter where it joins the outer hole portion 24. The diameter of the outer hole portion 24 is substantially constant along its length.

As a result of the tapered structure, the hole flow area in the hub region 20 is increased relative to the hole flow area in the mid-span region 18. Reduced coolant flow per unit of flow area in the hub region 20 reduces the hub region heat transfer coefficient and the amount of cooling. Turbine and blade design parameters determine the amount and length of taper to reduce or substantially eliminate overcooling in the hub region 20.

Tapering of the coolant holes also reduces pressure loss in the coolant holes. Accordingly, higher flow per unit of flow area is obtained in the mid-span region to obtain lower metal temperature for a given supply pressure at the blade root. Spanwise hole cooling tech-

nology can thus be employed with higher turbine inlet temperature levels. The higher flow per unit of flow area in the design section can also be used to reduce cooling flow for a given level of turbine inlet temperatures.

The embodiment shown in Figure 3 provides for reducing or eliminating overcooling in both the blade hub region 20 and the blade tip region 21. Thus, a coolant hole 16a includes a tapered hub portion 22a, a constant diameter mid-span portion 24a and a tip portion 25a which is tapered outwardly in the direction of coolant flow.

With an increased effective flow area in the tip hole portion 25a, reduced coolant velocity produces reduced heat transfer. Overcooling, which otherwise results from the effects of reduced centrifugal stress in the blade tip region 21, is thus substantially reduced or eliminated by appropriate choice of the amount and length of taper for the tip hole portion 25a. The major gain is further reduction in coolant pressure loss which permits lower coolant flow or increased cooling in the mid-span region 18.

The constant diameter mid-span portion 24a can be eliminated from the hole 16a so that the hole 16a is formed by the oppositely tapered portions 22a and 25a in end-to-end relation. The junction point of the hole portions 22a and 25a in this alternative would be determined by stress and heat transfer considerations.

To minimize pressure loss, it is preferred that the tapered hole portions be provided with continuous tapering, either linear as shown or nonlinear as warranted by design considerations. In addition, it is preferred that the coolant holes have a circular cross-section but the invention can be implemented with non-circular cross-sections.

In Figure 4, there is shown another embodiment of the invention in which a coolant hole 16b has a stepped configuration to provide a varying cross-section along its length for substantially reduced blade region overcooling.

In this case, the coolant hole 16b includes a hub portion 22b having an inner section 22b1 having a first diameter and an outer section 22b2 having a lesser diameter. A mid-span section 24b having a further reduced diameter adjoins the outer hub section 22b2. Finally, a tip portion 25b of the coolant hole 16b has a first section 25b1 and a second section 25b2 with successively greater diameters. The lengths and diameters of the various sections described for the coolant hole 16b are determined by stress and heat transfer considerations and provide substantially reduced blade region overcooling and, consequently, enhanced blade cooling and turbine efficiency.

Use of the tapered blade coolant holes provides a further advantage by permitting the blades to be manufactured by casting processes using cores for coolant hole formation. Thus, tapered cores can be employed to form the coolant holes 16 and 16a, and tapered cores with larger diameter in the hub and tip region are characteristically stronger than cores conventionally used to form constant diameter coolant holes in the airfoil. With stronger cores, there is reduced core breakage, reduced blade scrapping and reduced manufacturing costs.

In addition, the stronger tapered cores permit manufacture of smaller hole diameters in the mid-span portion of the coolant holes. In turn, improved blade cooling and reduced blade coolant flow can be realized.

What is claimed is:

1. A combustion turbine rotor blade having a root portion and an airfoil portion extending therefrom, said airfoil portion having a plurality of coolant holes extending from said root portion along its span to its tip to provide flow of coolant therethrough from said root portion, each of said coolant holes having an inner hub portion and a second portion extending outwardly from said hub portion, characterized by said hub and second hole portions having relative flow areas which cause the coolant to have reduced flow per unit of flow area in said hub hole portion relative to the coolant flow per unit of flow area through said second hole portion over a mid-span region of said blade thereby avoiding hub blade region overcooling.

2. A blade as set forth in claim 1 characterized by said hub hole portion being continuously tapered from a first flow area at its inlet end to a reduced flow area at its outlet end where it connects to said second portion.

3. A blade as set forth in claim 2 characterized by said second hole portion having a substantially constant flow area over its length.

4. A blade as set forth in claim 3 characterized by the flow area of said second hole portion being equal to the flow area of said hub hole portion at its outlet end.

5. A blade as set forth in claim 2 characterized by said second hole portion having a first section with a substantially constant flow area over its length equal to the flow area of said hub hole portion at its outlet end,

and a second section extending outwardly along the blade span from said first section, said second hole portion section having an inlet flow area equal to the first section flow area and tapering continuously outwardly to a larger flow area at its outlet end at the blade tip.

6. A blade as set forth in claim 1 characterized by said second hole portion including a mid-span section having a substantially constant flow area along its length, said hub hole portion having an inlet section with a substantially constant first flow area along its length and an outlet section coupled to said mid-span section and having a substantially constant second flow area less than said first flow area and a greater than the flow area of said mid-span section, and said second hole portion further having a first tip hole section coupled to said mid-span section and coupled to a second tip section providing an outlet at the blade tip, the flow area of said first tip section being greater than the flow area of said mid-span section and the flow area of said outlet tip section being greater than the flow area of said first tip section.

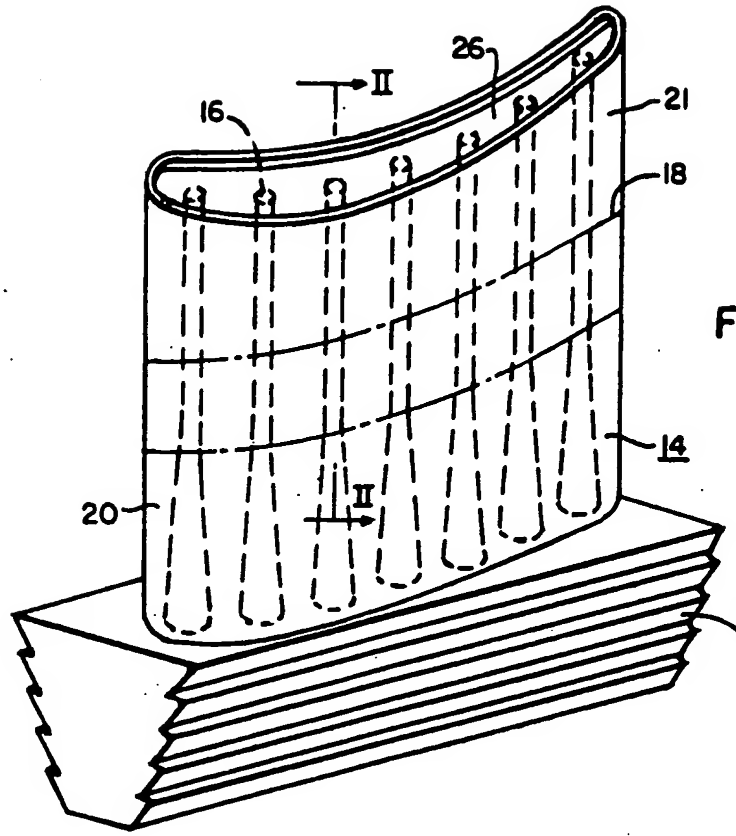

FIG.1.

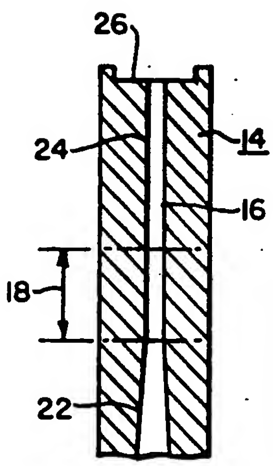

FIG.2.

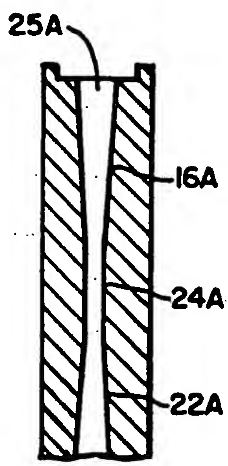

FIG.3.

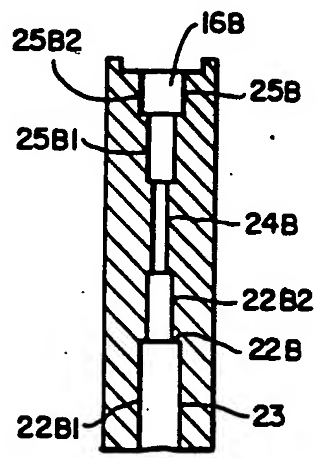

FIG.4.